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SOIL TREATMENTS FOR SUBTERRANEAN TERMITES

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The studies on which this paper is based were conducted in cooperation with the Department of Defense and private industry. H. C. Secrest, R. C. Morris, and V. K. Smith established many of the tests and collected many of the data.

SUMMARY

Since 1944 the Southern Forest Experiment Station's Forest Insect Laboratory at Gulfport, Mississippi, has been intensively studying chemical soil treatments for control of subterranean termites.

These studies have shown that 0.5 percent aldrin, 0.8 percent gamma benzene hexachloride, 1.0 percent chlordane, 0.5 percent dieldrin, 0.5 percent heptachlor, or 8.0 percent DDT will give many years of protection against subterranean termites. The DDT should be applied in fuel oil; the others in either water emulsions or fuel-oil solutions. These formulations are suggested for practical use either in preventing or controlling infestations in buildings.

The encouraging results obtained to date have prompted the expansion of the tests to include a wide range of concentrations and dosages. Hence the present recommendations as to chemicals and dosages are subject to change.

The keys to termite control lie in design and construction that prevent or discourage attack. Chemical soil treatments are a valuable supplement to good construction, but not a substitute for it.

The fundamental principle is to prevent the termites from establishing or maintaining their contact between the soil, from which they obtain moisture, and the woodwork of buildings, on which they feed. This could be accomplished, to a great extent, if architects, contractors, and home builders would give more consideration to the problem.

Termites can be discouraged by removing stumps, roots, and debris from the building site and by grading to keep the site dry. Adequate clearance between the soil and woodwork, as well as proper ventilation, should be provided for buildings having crawl space. Foundations should be impervious to termites—solid concrete is preferable. Hollow block or tile foundations should be capped with four inches of reinforced concrete or provided with good termite shields. Expansion joint fillers resistant to termite penetration should be used in slab-on-ground construction. Pressure-treated wood for sills, plates, and headers may be desirable where the hazard is extreme.

No matter how carefully constructed, however, any building made of wood that has not been treated with a preservative is more or less vulnerable to attack. In regions where termites are abundant, treating the soil with chemicals is advisable to provide additional protection. Chemical treatment of soil before pouring concrete slab floors is particularly valuable. Most of the cost of treating soil, either as a preventive or remedial measure, is the labor for application. Long-lasting chemicals are needed to reduce frequency of re-treating.

Soil treatments have been used in the United States for many years. Recently the search for more effective chemicals has been intensified. Most of this research is conducted by the Southern Forest Experiment Station's Forest Insect Laboratory, at Gulfport, Mississippi. The Laboratory has extensive field installations near Gulfport, and lesser ones in other parts of the United States and in the Panama Canal Zone.

This paper summarizes results with the best formulations found to date and discusses briefly their practical application. The studies are still in progress, and the list of suggested formulations is therefore subject to revision.

TEST METHODS

The first tests reported herein were installed during 1944 on the Harrison Experimental Forest, about 20 miles north of Gulfport. They were expanded in 1946, and at the same time a series was established in the Panama Canal Zone. Many new insecticides have been added since 1946. The Mississippi tests are located in a pine-hardwood forest on a light, sandy loam soil with a clay subsoil. The Canal Zone

tests are in a jungle area with a heavy soil that is high in organic content.

Several of the most promising formulations are being tried also under practical conditions in buildings damaged by termites. These practical applications were established during the period 1944 to 1953. They are in North Carolina in sandy soil.

Following are brief descriptions of the three test methods.

Ground-board tests are intended to determine the most effective formulations and dosages for treating the soil prior to pouring concrete slabs. All vegetation is removed from a 17-inch square of soil, then the chemical is sprinkled evenly over the soil surface. After the chemical has soaked in, an untreated sapwood pine board measuring 1 by 6 by 6 inches is laid flat on the ground in the center of the treated area, so that termites must cross or penetrate the treated soil before they can attack the board.

Stake tests simulate in certain respects the application of chemicals in trenches around the foundations of buildings. Two cubic feet of soil are removed to make a hole 15 inches in diameter and 19 inches deep. After the soil is treated with the desired dosage of chemical and replaced in the hole, a 2- by 4- by 18-inch untreated sapwood pine stake is driven to a depth of 12 inches in the center of the treated soil.

In both the ground-board and the stake tests, ten replicates of each treatment are used in a randomized block design. Treatments are considered to have failed when termites penetrate the treated soil and attack the wood. When 50 percent of the stakes or boards of a treatment are attacked, the test is closed.

Buildings tests are treatments of buildings that have become infested with termites. The chemicals are applied in shallow trenches along the inside and outside of concrete or brick foundations. Most buildings have two or three porches and at least one room with crawl space underneath. For inside treatments—i. e., those that are underneath the house and thus partially protected from the weather—each porch or room is considered a test unit. The outside treatments are largely around basement entrances, each entrance being regarded as a test unit. When termites penetrate the treated soil and construct tubes on the foundations, the treatment is considered to have failed.

RESULTS

The field installations, being fully exposed to the weather, are more severe trials than the building tests. In general, formulations and dosages that are effective in the ground-board or stake tests (tables 1 and 2) can be relied upon to give a high degree of protection to buildings. Several formulations that gave poor results in the field tests offered good protection beneath buildings (table 3).

In evaluating the data, it was considered that only formulations giving good results for at least 5 years in one or both types of field tests in Mississippi can be safely recommended for use in the United States. The following formulations, listed alphabetically, are among the best and most economical tested thus far:

1. Aldrin, 0.5 percent in No. 2 fuel oil or water emulsion.
2. Benzene hexachloride, 0.8 percent gamma in No. 2 fuel oil or water emulsion.
3. Chlordane, 1.0 percent in No. 2 fuel oil or water emulsion.
4. Dieldrin, 0.5 percent in No. 2 fuel oil or water emulsion.
5. DDT, 8.0 percent in No. 2 fuel oil.
6. Heptachlor, 0.5 percent in No. 2 fuel oil or water emulsion.

With any of the emulsions, a dosage of 1 to 1½ gallons per 10 square feet of surface area is recommended for overall treatment before pouring concrete slabs. Oil solutions should not be applied under slabs because they may damage certain vapor-barrier materials. Four gallons of either emulsions or oil solutions per 10 cubic feet of soil should be used for treating around foundations. These concentrations and dosages should provide a good margin of safety, so that a long period of protection can be expected.

For any given chemical the duration of protection depends to some extent on the quantity applied. Thus, in stake tests in Mississippi, a concentration of 4.0 percent DDT gave 90 percent protection for 6 years, whereas 8.0 percent was 90-percent effective for 11 years. Once failures begin, moreover, they generally increase rapidly. To illustrate, 8.0 percent DDT

Table 1.—*Ground-board tests of soil treatments: Mississippi and the Panama Canal Zone*

Formulation (approximate percentages by weight)	Location of test	Year established	Dosage per square foot	Proportion of ground-boards undamaged by termites after exposure for:[1]													
				1 year	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years	10 years	11 years	12 years	13 years	14 years
			Pints	*Percent*													
Aldrin																	
In water emulsion																	
0.25 percent	Miss.	1949	1	100	100	100	100	100	100	100	100	100	100	100			
0.50 percent	Miss.	1949	1	100	100	100	100	100	100	100	100	100	100	100			
1.00 percent	Miss.	1949	1	100	100	100	100	100	100	100	100	100	100	100			
Benzene hexachloride																	
In No. 2 fuel oil																	
0.40 percent gamma	Miss.	1948	½	100	100	100	100	90	50								
	Miss.	1948	1	100	100	100	100	100	100	90	90	60	40				
0.50 percent gamma	C.Z.	1951	1	100	70	50											
	C.Z.	1951	2	90	90	60	40										
0.80 percent gamma	Miss.	1948	1	100	100	100	100	100	100	100	90	90	60	60	40		
In water emulsion																	
0.40 percent gamma	Miss.	1948	½	100	100	80	70	70	60	60	60	20					
	Miss.	1948	1	100	100	100	100	100	100	80	80	80	70	40			
	C.Z.	1951	3	90	90	80	50										
0.80 percent gamma	Miss.	1948	1	100	100	100	100	100	100	100	100	90	70	60	50		
Chlordane																	
In No. 2 fuel oil																	
1.00 percent	Miss.	1948	½	100	100	100	100	100	100	100	100	100	100	100	100		
	Miss.	1948	1	100	100	100	100	100	100	100	100	100	100	100	100		
2.00 percent	Miss.	1948	½	100	100	100	100	100	100	100	100	100	100	100	100		
	Miss.	1948	1	100	100	100	100	100	100	100	100	100	100	100	100		
	C.Z.	1951	2	100	90	90	90	90	70	70	70	40					
In water emulsion																	
2.00 percent	Miss.	1948	½	100	100	100	100	100	100	100	100	100	100	100	100		
	Miss.	1948	1	100	100	100	100	100	100	100	100	100	100	100	100		
	C.Z.	1951	2	100	70	50	30										
	C.Z.	1951	3	100	100	70	70	70	60	40							
DDT																	
In No. 2 fuel oil																	
5.00 percent	Miss.	1946	½	100	100	100	70	50									
	Miss.	1946	1	100	100	100	100	80	80	80	80	80	80	80	80	60	50
	C.Z.	1951	1	90	80	60	50										
	C.Z.	1951	2	100	90	70	50										
In water emulsion																	
5.00 percent	Miss.	1951	½	90	60	30											
	C.Z.	1951	2	100	70	40											
Dieldrin																	
In No. 2 fuel oil																	
0.50 percent	C.Z.	1953	1	100	100	100	100	100	100	100							
	C.Z.	1953	2	100	100	100	100	100	100	100							
1.00 percent	C.Z.	1953	1	100	80	80	80	80	80	80[2]							
	C.Z.	1953	2	100	90	90	90	90	90	90[2]							
2.00 percent	C.Z.	1953	1	100	80	80	80	80	80	80[2]							
	C.Z.	1953	2	100	70	70	70	70	70	70[2]							
In water emulsion																	
0.25 percent	Miss.	1949	1	100	100	100	100	100	100	100	100	100	100	100			
0.50 percent	Miss.	1949	1	100	100	100	100	100	100	100	100	100	100	100			
1.00 percent	Miss.	1949	1	100	100	100	100	100	100	100	100	100	100	100			
	C.Z.	1953	2	100	70	70	70	70	70	70[2]							
	C.Z.	1953	3	100	80	80	80	80	80	80[2]							
2.00 percent	C.Z.	1953	2	100	90	90	90	90	90	90[2]							
	C.Z.	1953	3	100	70	70	70	70	70	70[2]							
Heptachlor																	
In No. 2 fuel oil																	
0.16 percent	Miss.	1956	1	100	100	100	100	100									
0.33 percent	Miss.	1956	1	100	100	100	100	100									
0.66 percent	Miss.	1956	1	100	100	100	100	100									
In water emulsion																	
0.16 percent	Miss.	1956	1	100	100	100	100	100									
0.33 percent	Miss.	1956	1	100	100	100	100	100									
0.66 percent	Miss.	1956	1	100	100	100	100	100									
1.00 percent	Miss.	1952	½	100	100	100	100	100	100	100	100						
2.00 percent	Miss.	1952	½	100	100	100	100	100	100	100	100						
Sodium arsenite																	
In water																	
10.00 percent	Miss.	1946	½	100	100	100	80	40									
	Miss.	1946	1	100	100	100	85	55	55								
	C.Z.	1946	1	100	100	...[3]	...[3]	100	95	45							
	C.Z.	1946	2	100	100	...	...	100	100	75	35						
Controls																	
Untreated	Miss.	1946	...	20													
	C.Z.	1946	...	50													

[1] Results are for the nearest full year.

[2] It is suspected that an error was made when these tests were read in 1955. What appeared to be light damage by termites was recorded then, but no further infestation has occurred.

[3] No data taken for these years.

Table 2.—*Stake tests of soil treatments: Mississippi and the Panama Canal Zone*

Formulation (approximate percentages by weight)	Location of test	Year established	Dosage per 10 cubic feet of soil	Proportion of stakes undamaged by termites after exposure for:[1]													
				1 year	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years	10 years	11 years	12 years	13 years	14 years
			Gallons	*Percent*													
Aldrin																	
In water emulsion																	
0.5 percent	Miss.	1952	3¾	100	100	100	100	100	100	100	100						
1.0 percent	Miss.	1952	3¾	100	100	100	100	100	100	100	100						
Benzene hexachloride																	
In kerosene																	
0.4 percent gamma	Miss.	1948	2½	100	100	100	100	90	60	60	40						
0.8 percent gamma	Miss	1946	2½	100	100	100	100	100	100	100	100	90	80	70	20		
	C.Z.	1946	2½	100	100	...[2]	...[2]	0									
In No. 2 fuel oil																	
0.5 percent gamma	C.Z.	1952	5	100	100	100	100	100	80	80	70						
In water emulsion																	
0.4 percent gamma	Miss.	1952	2½	100	100	100	100	100	90	60	50						
	C.Z.	1952	5	100	100	90	90	90	80	70	60						
0.8 percent gamma	Miss.	1952	3¾	100	100	100	100	100	100	100	100						
Chlordane																	
In No. 2 fuel oil																	
2.0 percent	Miss.	1951	4	100	100	100	100	100	100	100	100	100					
	C.Z.	1952	7½	100	100	100	100	100	100	100	100						
In water emulsion																	
0.5 percent	Miss.	1952	3¾	100	90	90	90	90	90	90	90						
1.0 percent	Miss.	1952	3¾	100	100	100	100	100	100	100	100						
2.0 percent	Miss.	1951	4	100	100	100	100	100	100	100	100	100					
	C.Z.	1952	7½	100	100	90	90	90	90	90	90						
DDT																	
In No. 2 fuel oil																	
4.0 percent	Miss.	1944	2½	100	100	100	100	90	90	70	70	60	50	30			
5.0 percent	C.Z.	1952	5	100	100	100	100	100	100	100	100						
8.0 percent	Miss.	1944	2½	100	100	100	100	100	90	90	90	90	90	90	70	60	10
In water emulsion																	
5.0 percent	Miss.	1952	3¾	90	80	80	80	80	40								
	C.Z.	1952	5	100	90	80	80	80	60	60	50						
Dieldrin																	
In No. 2 fuel oil																	
0.5 percent	C.Z.	1953	5	100	100	100	100	100	100	100							
1.0 percent	C.Z.	1953	5	100	100	100	100	100	100	100							
2.0 percent	C.Z.	1953	5	100	100	100	100	100	100	100							
In water emulsion																	
1.0 percent	Miss.	1952	3¾	100	100	100	100	100	100	100	100						
	C.Z.	1953	7½	100	100	100	100	100	100	100							
2.0 percent	Miss.	1952	3¾	100	100	100	100	100	100	100	100						
	C.Z.	1953	7½	100	90	90	90	90	90	90							
Heptachlor																	
In No. 2 fuel oil																	
0.16 percent	Miss.	1956	4	100	100	100	100	100									
0.66 percent	Miss.	1956	4	100	100	100	100	100									
In water emulsion																	
0.16 percent	Miss.	1956	4	100	100	100	100	100									
0.33 percent	Miss.	1956	4	100	100	100	100	100									
0.66 percent	Miss.	1956	4	100	100	100	100	100									
1.33 percent	Miss.	1956	4	100	100	100	100	100									
Sodium arsenite																	
In water																	
10.0 percent	Miss.	1948	3¾	100	100	100	100	100	100	100	100	80	80	80	80		
Trichlorobenzene																	
In No. 2 fuel oil																	
25.0 percent (vol.)	Miss.	1948	3¾	100	100	100	100	90	80	70	60	50					
	C.Z.	1952	5	100	100	100	80	70	60	60	60						
In water emulsion																	
25.0 percent	Miss.	1948	3¾	100	100	100	80	80	70	60	50						
Controls																	
No. 2 fuel oil	Miss.	1948	3¾	100	80	40											
	C.Z.	1948	5	20	0												
Untreated	Miss.	1948	...	20	10												
	C.Z.	1948	...	50	0												

[1] Results are for the nearest full year.
[2] No data taken for these years.

was 90 percent effective for 11 years, 70 percent for 12 years, and only 10 percent for 14 years. Since the cost of the chemical usually is only a small portion of the total cost of treating a building, it is false economy to use less than the quantities recommended.

Much heavier dosages and concentrations are necessary in the Canal Zone than in Mississippi. In ground-board tests in Mississippi, for example, 2.0-percent chlordane emulsion at a dosage of one pint per square foot is still 100-percent effective after 11 years; in the Canal Zone a dosage of 2 pints per square foot failed during the fourth year.

Both sodium arsenite and trichlorobenzene give good control for several years, but they are not so long-lasting as the chemicals now suggested, are more expensive, and are toxic to plants. For these reasons, they are no longer recommended.

Chemicals that have given 50 percent or less protection for five years in stake and ground-board tests (when tested at practical concentrations and rates of application) are considered inferior to those listed on page 2. These include acetylene tetrachloride, chlorinated nitrotoluene, copper ammonium fluoride, copper naphthenate, copper sulphate, coal-tar creosote, coal-tar creosote plus orthodichlorobenzene, hexachloroethane, lead arsenate, methoxychlor, monochloronaphthalene, orthodichlorobenzene, pentachlorophenol, sodium dinitroorthocreosolate, and zanthane.

Table 3.—*Effectiveness of soil treatments in controlling termites in buildings during about 14 years of service*

Formulation	Dosage per 10 lineal feet	Underneath buildings			Outside of buildings			Total		
		Units treated	Undamaged		Units treated	Undamaged		Units treated	Undamaged	
	Gallons	*No.*	*No.*	*Percent*	*No.*	*No.*	*Percent*	*No.*	*No.*	*Percent*
Coal-tar creosote										
In No. 2 fuel oil										
50.0 percent	2	19	18	95	8	5	63	27	23	85
Chlorinated toluene (2-chloro-6-nitro-toluene)										
In No. 2 fuel oil										
25.0 percent	2	23	23	100	8	4	50	31	27	87
DDT										
In No. 2 fuel oil										
5.0 percent	4	59	2	97	28	7	75	87	78	90
10.0 percent	4	22	22	100	7	4	57	29	26	90
In water emulsion										
5.0 percent	4	39	38	97	4	2	50	43	40	93
Orthodichlorobenzene										
In No. 2 fuel oil										
25.0 percent	2	86	77	90	19	7	37	105	84	80
	4	6	6	100	2	0	0	8	6	75
Pentachlorophenol										
In No. 2 fuel oil										
5.0 percent	4	17	14	82	3	1	33	20	15	75
Sodium arsenite										
In water										
10.0 percent	2	40	40	100	0	...	...	40	40	100

PRACTICAL APPLICATION OF SOIL TREATMENTS

Soil treatments are practical and effective not only in helping to prevent attack on buildings, but in stopping existing infestations. Since there are many variations in construction, detailed discussion of treatments is impractical. The essential thing is to apply the insecticide in such a way that it forms a barrier to termite entry.

Preventive Measures

Slab-on-ground construction is very susceptible to termite attack, and remedial measures are difficult and expensive. Protection can be secured for many years by treating the soil, before the slab is poured, with any one of the previously listed emulsions.

Treatment should be made after all filling and grading is complete. Critical areas, such as along foundation walls and around plumbing, should be treated by the trenching method described later under remedial measures. In addition, an overall surface treatment at a dosage of not less than 1 gallon per 10 square feet is recommended if the fill is soil or unwashed gravel. If cinders, washed gravel, or similar coarse material is used in the fill, the dosage should be increased by at least one-half.

Voids in hollow-block foundations should be treated with at least 2 gallons per 10 linear feet of wall. For buildings having crawl space or basements, the trench and void treatments can be used as preventive measures without an overall surface application.

Remedial Measures

When buildings on concrete slabs become infested with termites, it is difficult to get the chemicals where they will be effective. One method is to drill holes through the slab at any point where termites may enter; the holes should be spaced about a foot apart. Another method is to drill through the foundation walls from the outside and force the chemical just underneath the slab along the inside of the foundation and along expansion joints. Any one of the formulations listed on page 2 should be applied at the rate of 4 gallons per 10 linear feet of foundation or expansion joint.

To treat buildings having crawl space or basements, a trench can be dug adjacent to and around all piers and pipes and along the sides of foundation walls. A trench 6 to 8 inches deep and about the same width is ample for solid concrete foundations that have not developed cracks. While the trench is open, one of the recommended formulations should be poured in at the rate of 2 gallons per 10 linear feet of trench. Then, as the excavated soil is put back into the trench, it also should be treated at the rate of 2 gallons per 10 linear feet. This rate of application is equal to about 4 gallons per 10 cubic feet of soil if it is assumed that the chemical spreads downward and outward from the trench. For brick, hollow block, and concrete foundations that have cracked, the trench should be dug to the footing. This is to prevent termites from gaining hidden entry through voids. The amount of chemical applied in deep trenches should be increased correspondingly. Voids in hollow-block foundations should be treated as described under preventive measures.

WARNING! All of these chemicals are poisonous if taken internally, and some of them can be absorbed through the skin. If they are spilled on the body, they should be washed off immediately with warm, soapy water. The oil solutions will damage plants if applied to their roots.